PB-218 492

DANGER IN THE AIR: SULFUR OXIDES AND PARTICULATES

National Air Pollution Control Administration
Washington, D. C.

May 1970

DISTRIBUTED BY:

NTIS

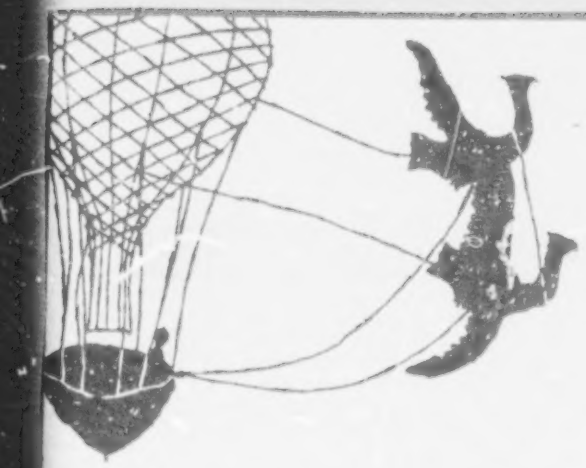
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

PB 218 492

DANGER IN THE AIR: SULFUR OXIDES AND PARTICULATES

U.S. Department of
Health, Education, and Welfare
Public Health Service · Environmental Health Service



DANGER IN THE AIR:

SULFUR OXIDES AND PARTICULATES

Sulfur oxides and particulate matter in the air can . . .

- Aggravate respiratory disorders, such as coughing, chest colds, asthma, and pneumonia.
- Increase the incidence of emphysema, lung cancer, and chronic bronchitis.
- Lead to higher death rates, especially among the very young, the very old, and persons suffering from chronic heart or lung disease.
- Send more people to the hospital.
- Keep more people home from work.
- Corrode metals, dirty and erode buildings, soil and destroy clothing, curtains, and other fabrics.
- Damage statues, paintings, books and other works of art.
- Injure or kill crops, flowers, shrubs, and trees.
- Reduce visibility, thus hindering transportation and endangering the safety of air and highway travelers.
- Alter weather and climate.
- Blight our surroundings and diminish our enjoyment of life.
- Cost billions of dollars a year. Everyone, individuals and organizations alike, pays a price.

SULFUR OXIDES and PARTICULATE MATTER are two major air pollutants. They account for almost 30% of the 210 million tons of wastes man pours annually into the atmosphere over the United States.

The major source of sulfur oxides in the air is the burning of coal and oil. These fuels often contain significant amount of sulfur. When burned, they give off large amounts of sulfur dioxide and lesser amounts of sulfur trioxide.

Sulfur dioxide is a colorless, nonflammable, nonexplosive gas. It is highly soluble in water. You can taste it in the air in concentrations of over 860 micrograms per cubic meter ($\mu g/m^3$). Above 8000 $\mu g/m^3$ it has an odor that is pungent and irritating to most people.

In the atmosphere, sulfur dioxide reacts with other materials to form sulfur trioxide, sulfuric acid, and salts of sulfuric acid. Sulfur trioxide immediately changes to sulfuric acid when water is present.

Sulfur dioxide gas alone can irritate the upper respiratory tract. Carried deep into the lungs on particles, it can injure delicate tissue. Sulfuric acid can also penetrate deep into the lungs and damage tissue.

Particulate matter—minute pieces of solids or liquids dispersed in the atmosphere—is also produced primarily by combustion. Particles of major concern in air pollution range in size from 0.005 microns to about 250 microns in radius. (A micron is one-millionth of a meter. The size of the period at the end of this sentence is about 1000 microns.)

Particles of this size range stay in the air anywhere from a few seconds to several months.

Particulates constitute a significant fraction of the pollutants in the air of our cities. They are composed of bits of carbon, ash, oil, and grease, as well as microscopic amounts of metal and metal oxides. The air pollution we can see—dust, smoke, haze, mist—results principally from particulates.

If air pollution is to be controlled—as the public demands and as Congress has directed—it must be understood.

Present day air pollution is man-made. The man who lighted the first fire was polluting the air around him. It mattered little in a nearly empty world. But as man increased in numbers, lighting more fires, the problem of air pollution grew.

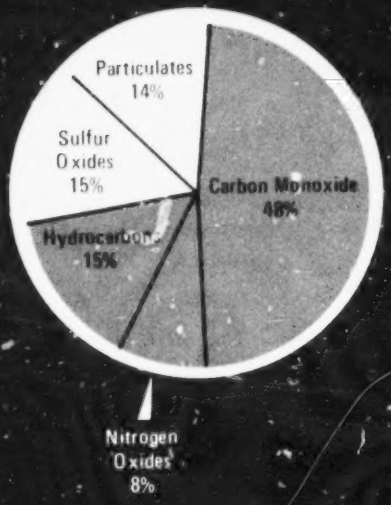
Today air pollution is an environmental problem of major proportions.

It is an unwanted product of a complex and highly industrialized society. It is a product of the Nation's factories, mills, and power plants. It is a product of the fuel we burn to light, heat, and cool our homes; to power the machines which produce the goods and services we need and desire; and to propel our cars, trucks, buses, trains, planes, and boats. It is a product of our growing population. It is a product of our crowded cities.

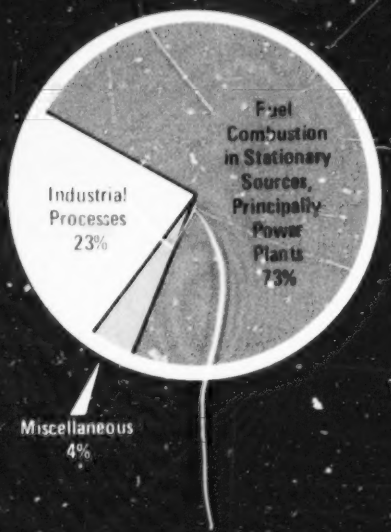
Air pollution is an unwanted product of an expanding and affluent economy. The more we produce, the more we pollute.

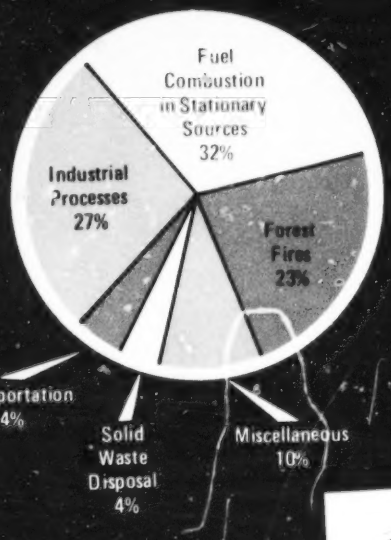
SULFUR OXIDES AND PARTICULATES EMITTED INTO THE U.S. ATMOSPHERE . . . .

ACCOUNT FOR ALMOST 30% OF TOTAL EMISSIONS



COME FROM A VARIETY OF SOURCES

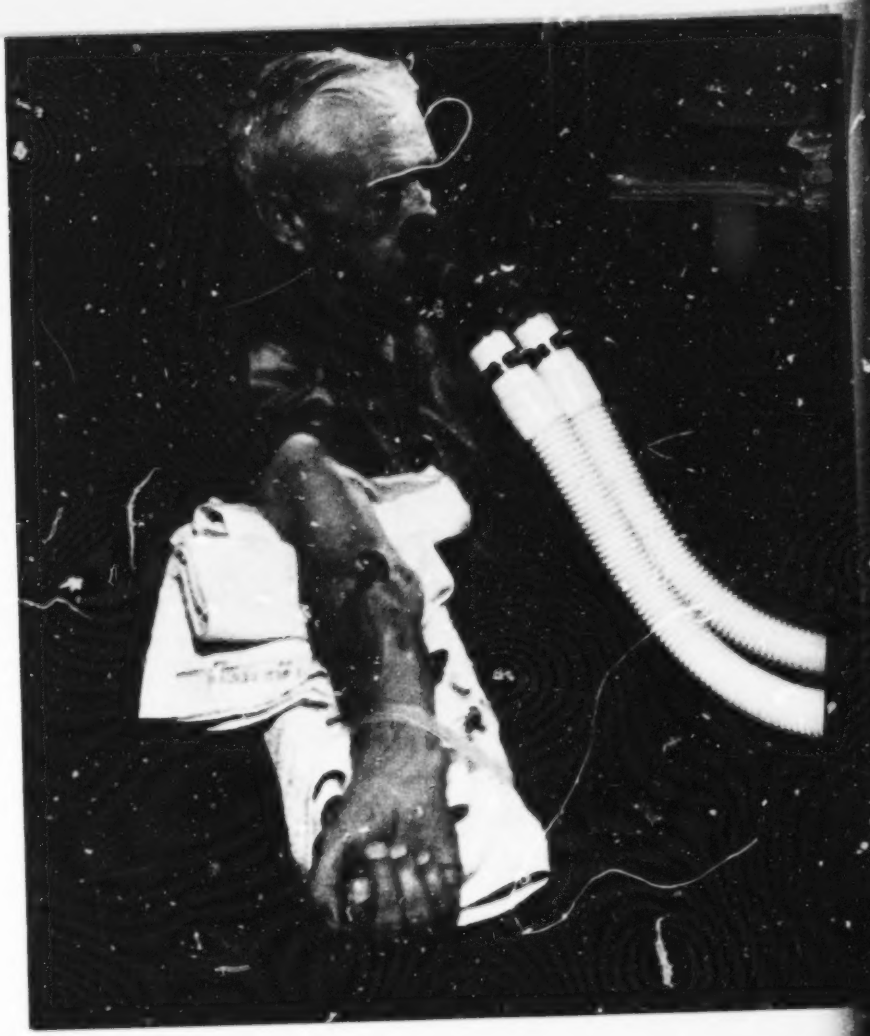




They Can Damage Human Health

The most serious single consequence of air pollution is its impact upon the health of human beings. Sulfur oxides irritate the respiratory system, causing both temporary and permanent injury. When small particles are breathed in with sulfur oxides, the irritation—and injury—may increase significantly.

The health hazards of air polluted with sulfur oxides and particles have been demonstrated in a number of air pollution disasters—in the Meuse Valley in Belgium in 1930; in Donora, Pennsylvania, in 1948; in London in 1952, 1955, 1956, 1957, 1959, and 1962; in New York City in 1953, 1962, 1963, 1964, and 1966; in Osaka in 1962; in Rotterdam in 1959 and 1962. The London smog of 1952, which took 4000 lives, is the greatest single air pollution tool on record.



"Clean air, clean water, open spaces—these should once again be the birthright of every American. If we act now—they can be.

"We still think of air as free. But clean air is not, and neither is clean water. The price tag on pollution control is high. Through our years of past carelessness we incurred a debt to nature, and now that debt is being called."
President Richard M. Nixon, in his State of the Union Address, January 22, 1970

In all of these episodes of acute air pollution, concentrations of sulfur oxides and particulates in the air increased sharply above normal levels—and so did the death rate. Victims were usually the very young, the very old, or people with chronic heart or lung disease. But the general population was also harmed.

In addition to increased deaths in these incidents sickness increased. Hospital admissions rose. Doctors received more calls. Absenteeism from work increased. Such acute, short term episodes of air pollution are only the tip of the iceberg, however. There is evidence that long-term exposure to air polluted with lower concentrations of sulfur oxides and particulates—concentrations relatively common in many urban and industrial areas—is related to increased illness.

Coughing, difficulty in breathing, bronchitis, asthma, heart disease, pneumonia, chest colds—all these, studies indicate, may afflict a person who lives for a long time in a polluted area.

Emphysema, the fastest growing cause of death in the United States, also has been linked to air pollution. One study found four times more emphysema among cigarette smokers in a polluted urban area than among smokers in a rural area. Among nonsmokers, mild-to-moderate emphysema was three times more frequent in the polluted urban area than in the rural area.

Sulfur oxides and particulates may begin to affect human health long before clear cause-and-effect relationships become obvious. For example, one study of a polluted area found that repeated respiratory infections among children may have contributed to development of chronic bronchitis when they become adults.

Evidence shows that health may be affected adversely when the annual mean concentration of sulfur dioxide in the air rises above 115 micrograms per cubic meter ($\mu g/m^3$) or 0.04 parts per million (ppm). Deaths may increase from bronchitis and from lung cancer when this level of sulfur dioxide is accompanied by smoke concentrations of about 160 $\mu g/m^3$.

The annual mean concentration of sulfur dioxide in the air in Chicago in 1968 was 331 $\mu g/m^3$; in Philadelphia it was 228 $\mu g/m^3$.

Evidence shows that when the daily mean concentration of sulfur dioxide ranges from 300 to 500 $\mu g/m^3$, more older persons may be admitted to the hospital for respiratory disease and absenteeism from work may increase.

Sulfur dioxide concentrations during 1968 exceeded the daily mean of 300 $\mu g/m^3$ on 131 days in Chicago, 75 days in Philadelphia, 17 days in Washington, D.C. and 7 days in St. Louis.

Evidence shows that when the annual geometric mean concentration of particulates in the air ranges from 80 to 100 $\mu g/m^3$—and is coupled with pollution from sulfur oxides—death rates may increase among persons over 50.

Chicago, Cincinnati, Denver, St. Louis, Philadelphia, and Washington exceeded these particulate levels in 1968.

Evidence shows that when particulate concentrations in the air persist at a daily average above 300 $\mu g/m^3$—accompanied by sulfur dioxide concentrations exceeding 630 $\mu g/m^3$—chronic bronchitis patients are likely to become acutely worse.

In 1968, Denver had 26 days when the daily average for particulates exceeded 300 $\mu g/m^3$; St. Louis had 9 days; Philadelphia had 7.

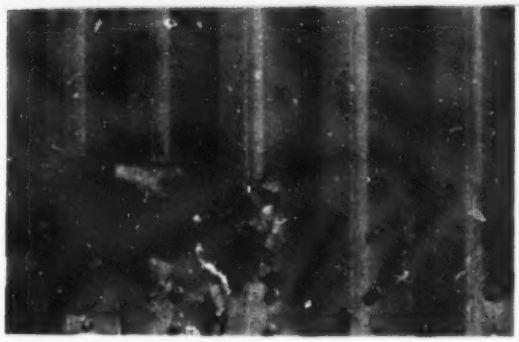
They Can Destroy Property

Sulfur oxides and particulates can attack and damage man's property and possessions. Much of this damage results when sulfur oxides are converted into highly destructive sulfuric acid. Particulates, too, can damage many buildings and materials. In combination, they can be even more destructive.

Sulfur oxides can speed corrosion of iron, steel, and zinc. When both particulate and sulfur oxides levels are relatively high—in the fall and winter, for example, when more fuel is used for heating—corrosion rates are higher. Studies have shown corrosion rates are 1½ to 5 times greater in polluted urban areas than in rural areas. Some metals corrode more in the heavily polluted air of industrial areas than in many marine and tropical locations. Oily and tarry particles commonly found in industrial and urban areas are serious factors in corrosion and failure of electrical contacts, connectors, and components.

It is difficult to pinpoint the effects of each of the pollutants on the corrosion of metals, since they generally occur together. However, some information is available.

The national program to control air pollution is directed by the National Air Pollution Control Administration, a part of the Environmental Health Service of the Department of Health, Education, and Welfare. This booklet is one of a series prepared to inform the public of the nature of the air pollution problem and of the action which must be taken to control it.



As part of the National Air Pollution Control Administration's national air surveillance network, the air in several representative urban areas is continuously sampled and analyzed. In 1968, the air was monitored in downtown sections of Chicago, Cincinnati, Denver, Philadelphia, St. Louis, and Washington, D.C. Sulfur oxides and particulate levels in these cities are cited throughout this booklet for the purpose of comparing actual levels with levels at which effects on health and property have been observed.

Evidence shows that at an annual mean sulfur dioxide level of about 86 $\mu g/m^3$ (0.03 ppm)—accompanied by high particulate levels—steel panels lose more than 10% of their weight in one year.

Chicago's annual mean concentration of sulfur dioxide in 1968 was 331, Philadelphia's was 228, Washington's was 106, and St. Louis's was 80.

Evidence shows that at annual mean geometric concentrations ranging from 60 to 180 $\mu g/m^3$ of particulates—in the presence of sulfur dioxide and moisture—steel and zinc corrode more rapidly.

Chicago's annual mean for particulates in 1968 was 165 $\mu g/m^3$ and Denver's was 157. Practically all urban areas throughout the Nation have annual mean concentrations of at least 60 $\mu g/m^3$—concentrations within the range in which metals corrode.

Sulfur oxides can physically deteriorate and discolor buildings. Limestone, marble, and other building stones, as well as mortar and roofing slate, are attacked by the acids formed by the interaction of industrial smoke and moisture.

Particles alone can soil, disfigure, and damage stone, brick, paint, glass, and composition materials. They coat surfaces with soot and grit, pit and stain auto finishes, and blister other painted surfaces.

Some of the finest historical monuments—public buildings, cathedrals, sculpture—have deteriorated more rapidly in recent years because increasing industrialization has led to increased emissions of sulfur oxides and particulates. Cleopatra's Needle has deteriorated more since it was moved to New York City in the late 19th century than in all of the 2,000 or so years it stood in Egypt.

Air pollution can damage and fade clothing, curtains, and other fabrics. The acids formed from sulfur oxides attack cotton, linen, rayon, and nylon. (Many a run in nylon stockings in polluted cities is caused by air pollution, not a hang-nail.) Soot and fumes can deteriorate and soil fabrics. Even if not directly disintegrated by air pollutants, fabrics in polluted atmospheres need more frequent washing or cleaning, adding a dollar cost and shortening the life of the fabric.

Sulfur dioxide can weaken and disintegrate leather; book bindings can be damaged and even destroyed. Paper can be yellowed, made brittle, and ultimately destroyed by air pollutants.

They Can Destroy Vegetation

Sulfur dioxide in air is a major cause of damage to vegetation. Many plants are more sensitive to this pollutant—at both short-term high concentrations and long-term low concentrations—than are humans and animals.

Sulfur dioxide can injure plant tissue, discolor leaves, stunt plant growth, and reduce crop yields. Sulfuric acid mist found in some fogs also damages vegetation. Sulfur pollutants have injured spinach, alfalfa, barley, rye, endive, romaine, beets, cotton, celery, tobacco, chicory, citrus fruits, cantaloupe, apple and pear trees, mountain ash, pine, western larch, Pacific ninebark, spirea, fir, and a wide variety of flowers.

More than one-third of the home gardens studied near a smelter showed damage by sulfur pollutants. Near another smelter, almost 9 out of 10 gardens were damaged by sulfur oxides. Some 15 tree species—both conifers and hardwoods—have been damaged by sulfur oxides from nearby petroleum refineries. Plant damage has been noted as far as 52 miles downwind from a smelter emitting large amounts of sulfur dioxide.

Evidence shows that chronic plant injury and excessive leaf drop occur at annual mean concentrations of about 85 $\mu g/m^3$ (0.03 ppm) of sulfur dioxide.

Chicago's annual mean concentration of sulfur dioxide in 1968 was 331 $\mu g/m^3$; Philadelphia's was 228, Washington's was 106, and St. Louis's was 80.

Evidence shows that after exposure to about 860 $\mu g/m^3$ of sulfur dioxide for 8 hours, some species of trees and shrubs are injured.

This 8-hour concentration of sulfur dioxide in the air was exceeded on at least 20 days in Chicago and 7 days in Philadelphia in 1968.

Particulates can also damage plants and trees. Dry dusts from certain industrial operations, while relatively harmless alone, solidify with moisture into hard crusts which can injure plant tissue, inhibit growth, and interfere with pollination. Dust deposits can increase insect injury to plants by killing predators, thus making plants more susceptible to attack and disease.

Particulates carrying harmful chemicals have also damaged vegetation—and harmed cattle and sheep grazing on contaminated plants. Fluorides from fertilizers plants have ruined thousands of acres of citrus groves and withered large areas of shrubbery.

Even some national parks have been threatened by pollutants drifting from urban and industrial areas many miles away.

They Can Reduce Visibility

Air pollution is a regional problem, for the wind does not respect the man-made boundaries of cities, counties, and states. If air pollution control efforts are to be effective, then, they must accommodate such factors as meteorology, topography, the extent of urban-industrial concentration, the nature and location of pollution sources, and social and political considerations. If air pollution control efforts are to be effective, they must encompass all parts of a region.

Air pollution can reduce visibility. It can obscure our view of city skylines and nature's scenic grandeur. It can diminish esthetic enjoyment of our surroundings.

Decreased visibility interferes with safe operations of aircraft and automobiles, as well as disrupting transportation schedules. Poor visibility resulting from air pollution has been important in both automobile and aircraft accidents. In one recent year, low visibility caused by smoke, haze, and dust was the suspected cause of 15 to 20 plane crashes, according to government records.

Particulate matter is the major villain. As particle levels go up, visibility goes down. Particles suspended in the air scatter and absorb light coming from an object and its background, thereby reducing the contrast between them. In addition, particles scatter light into the line of sight, illuminating the air and further reducing the contrast. The scattering of light into and out of the line of sight by particles of 0.1 to 1 micron radius has the greatest effect on visibility.

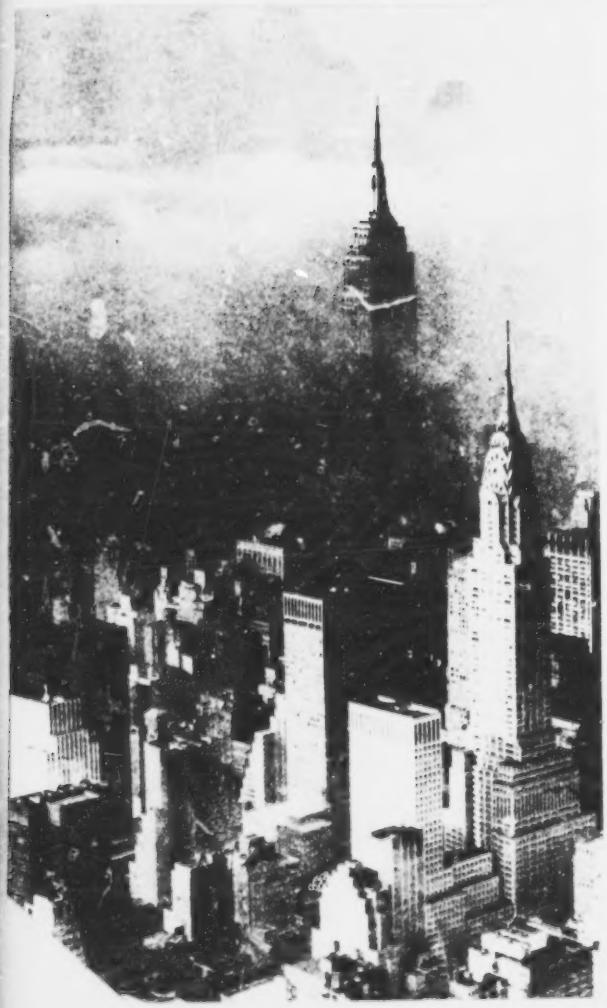
Of the particles suspended in urban air, from 5 to 20% consist of sulfuric acid mist and other sulfates; of these, at least 80% by weight are smaller than 1 micron in radius. Consequently, suspended sulfates in air can contribute significantly to reduction in visibility.

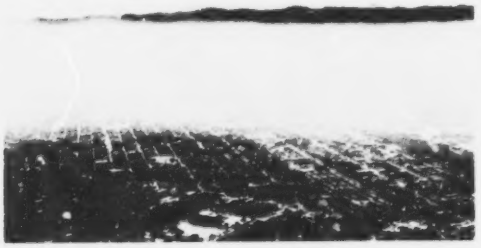
Evidence shows that at a concentration of about 150 $\mu g/m^3$ of particulates in air—with the predominant particle size ranging from 0.2 to 1.0 microns and with relative humidity at less than 70%—visibility is reduced to as low as 5 miles.

In 1968, particulate concentrations were at least 150 $\mu g/m^3$ more than half the time the air in Chicago was sampled for particulates. Over 40% of the days measured in Denver, Philadelphia, and St. Louis averaged more than 150; in Washington the figure was 30%, and in Cincinnati 18%.

Evidence shows that a concentration of about 285 $\mu g/m^3$ (0.10 ppm) of sulfur dioxide in air—with a comparable concentration of particulate matter and relative humidity at 50%—visibility may be reduced to about 5 miles.

In 1968, daily mean levels of sulfur dioxide exceeded 285 $\mu g/m^3$ on 137 days in Chicago, 89 days in Philadelphia, 20 days in Washington, and 8 days in St. Louis.





They Can Affect Weather

The opportunities for individuals and citizens' groups to participate constructively in the efforts to control air pollution are greater than they have ever been before. Under the Clean Air Act, States will hold public hearings at which citizens and groups who have a sincere interest in removing the pollutants from the air they breathe can—and they by all means should—make their voices clearly heard on behalf of effective control programs.

One of the most intriguing aspects of air pollution is its effect on weather and climate. Particulates emitted into the air scatter light and give the sky its variable hues, its colorful dawns and sunsets—and its dense hazes and dark urban palls.

Particles are essential for cloud formation; without particles liquid water clouds could not form except when the air was supersaturated. However, nature supplies in over-abundance the particles required for cloud formation. Thus, introduction of man-made particulate matter into the atmosphere can alter the cloud-forming process and precipitation patterns.

In some sections of the country, precipitation patterns have already been affected by emissions of particulates—inadvertent cloud seeding by industrial pollutants.

Tulsa, Oklahoma, has grown from a village to a city in the past 50 years. With this growth has come a steady increase in concentrations of particles in its atmosphere—and a gradual increase in rainfall.

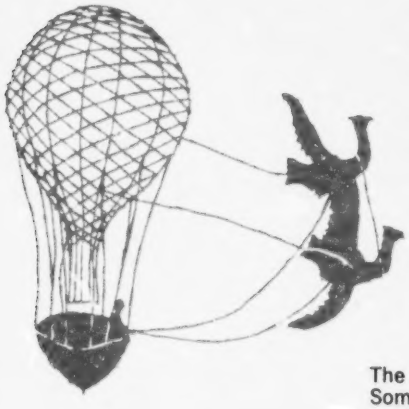
In Louisville, Pittsburgh, and Buffalo, reduced rainfalls on Sundays have been associated with the reduced industrial activity on those days, which reduces levels of particulates. Snow patterns in Toronto show a similar correlation with particulates.

In La Porte, Indiana—30 miles downwind from the heavy industrial complex in Chicago—precipitation has increased significantly since 1925. For over 60 years, La Porte's precipitation peaks have coincided with peaks in steel production in the Chicago area. Other studies have shown that smoke from steel furnaces increases rainfall downwind.

Particulates can also reduce the amount of sunlight reaching cities. Leningrad has an estimated 70% less sunlight in winter because of particulates. Daylight illumination in the center of London has been measured at 20% lower than in slightly less polluted parts of the city. Other studies suggest that cities in general receive 15 to 20% less total solar radiation—because of particles in their atmosphere—than rural areas.

Evidence shows that at particulate concentrations ranging from 100 to 150 $\mu g/m^3$—accompanied by large smoke turbidity—direct sunlight in middle and high latitudes is reduced up to one-third in summer and two-thirds in winter.

It would be hard to find a city of over 50,000 population which has not experienced periods of over 100 $\mu g/m^3$, the lower side of the range.



The Costs of Air Pollution

The total costs of air pollution are incalculable. Some specific costs can be measured—the cost of washing a shirt or cleaning a building, of depressed property values, of crop and livestock losses, of air travel disruptions. Other costs are immeasurable—the shortened human life with its reduced productivity.

The total costs of air pollution cannot be established precisely because atmospheric contamination stems from a complex interaction of a multitude of factors. But all indications are that air pollution costs the people of the United States many billions of dollars a year.

Economic studies are beginning to pinpoint a few estimates: the cost of painting steel structures damaged by air pollution (particulate matter, primarily) is approximately $100 million a year. The cost of commercial laundering, cleaning, and dyeing of fabrics soiled by air pollution is about $800 million a year. The cost of washing cars dirtied by air pollution is about $240 million a year. The cost of damage to agricultural crops and livestock from air pollution could be $500 million a year or more. The cost of air pollution's adverse effects on air travel has been estimated at from $40 million to $80 million a year.

Air pollution also imposes many other costs which cannot be measured. Among them:

- Hospital bills, doctor bills, and medicines for people made sick by air pollution.
- Time lost from work by those incapacitated by air pollution—and the resulting reduction in productivity in business and industry.
- Added maintenance and painting of buildings and homes.
- Damaged equipment, materials, and fabrics.
- Clean air required to protect expensive equipment and to safeguard the purity of foods, beverages, and other products.

- Injuries and property damage caused by reduced visibility.
- Burning lights in cities darkened by air pollution.
- Property values reduced by air pollution.
- Wasted fuel whenever a black plume (a sign of incomplete combustion) rises from a chimney or trails from a jet plane.
- Sulfur (a valuable chemical) wasted into the air, instead of being conserved, when coal and oil are burned.
- Livestock injured or killed by air pollutants.

One recent study estimated that air pollution in New York City could impose costs of up to $850 a year on each family living there for extra cleaning, household maintenance, and personal care. This is in addition to the costs imposed on the city's nearly 10 million daytime inhabitants.

And what of those effects of air pollution on which no price tag can be placed:

- What of the cost of chronic suffering and discomfort to those plagued with poor health caused or aggravated by air pollution?
- What of the cost of man's total sense of well-being when his city is shrouded in a haze of air pollution?
- What of the cost of blackening the countryside, of killing flowers and trees?
- What of the cost of irreplaceable art treasures defaced by air pollution?
- What of the cost of the insult to our senses and to our dignity by obnoxious odors, even when they pose no threat to our health?

These are values beyond the market place. Nevertheless, they are among those values which make up the quality of life and which should not be diminished by air pollution.

What is an effective air pollution control program? In answering this question, the citizen must first consider damage to health, the most important effect of air pollution. But he must consider the effects of both short-term and long-term exposures. He may also want to consider the economic and esthetic benefits to be obtained from low concentrations of sulfur oxides and particulate matter as related to visibility, soiling, corrosion, agricultural damage, weather changes, and other less obvious effects. Further, he may want to consider the margins of safety needed to protect against effects which may be occurring below the levels cited in this booklet.

Toward Clean Air

The death, damage, destruction, and degradation inflicted on man and his environment by air pollution have reached alarming proportions. A massive counterattack is needed if we are to stop degrading our environment, perhaps beyond recall.

On February 10, 1970, President Richard M. Nixon affirmed his determination to launch that counterattack as he sent to Congress a 37-point program to rescue the Nation's environment. Calling air "our most vital resource" and its pollution "our most serious environmental problem," he proposed amendments to the Clean Air Act to enlarge the scope of the national program to abate air pollution.

But legislation is not a magic wand to wave and cleanse our skies. It will be effective, and we will have clean air, only if all of us—industry, governments at all levels, and concerned citizens—fulfill our respective responsibilities. It will be effective only if the people make it so.

The cost of bringing air pollution under control has been estimated to be over a billion dollars annually above what we are spending now. Compared to all the costs we now pay for the damage done by air pollution, clean air would obviously be a bargain. To achieve this bargain—to have an environment with air fit to breathe—citizens must convince those making the decisions that action can and must be taken now.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 386-624